

Climate-sensitive Forest Growth Models: How Well Can Data from the Past Predict the Future?

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Global warming undermines almost all the rules that environmental stewards have lived by.

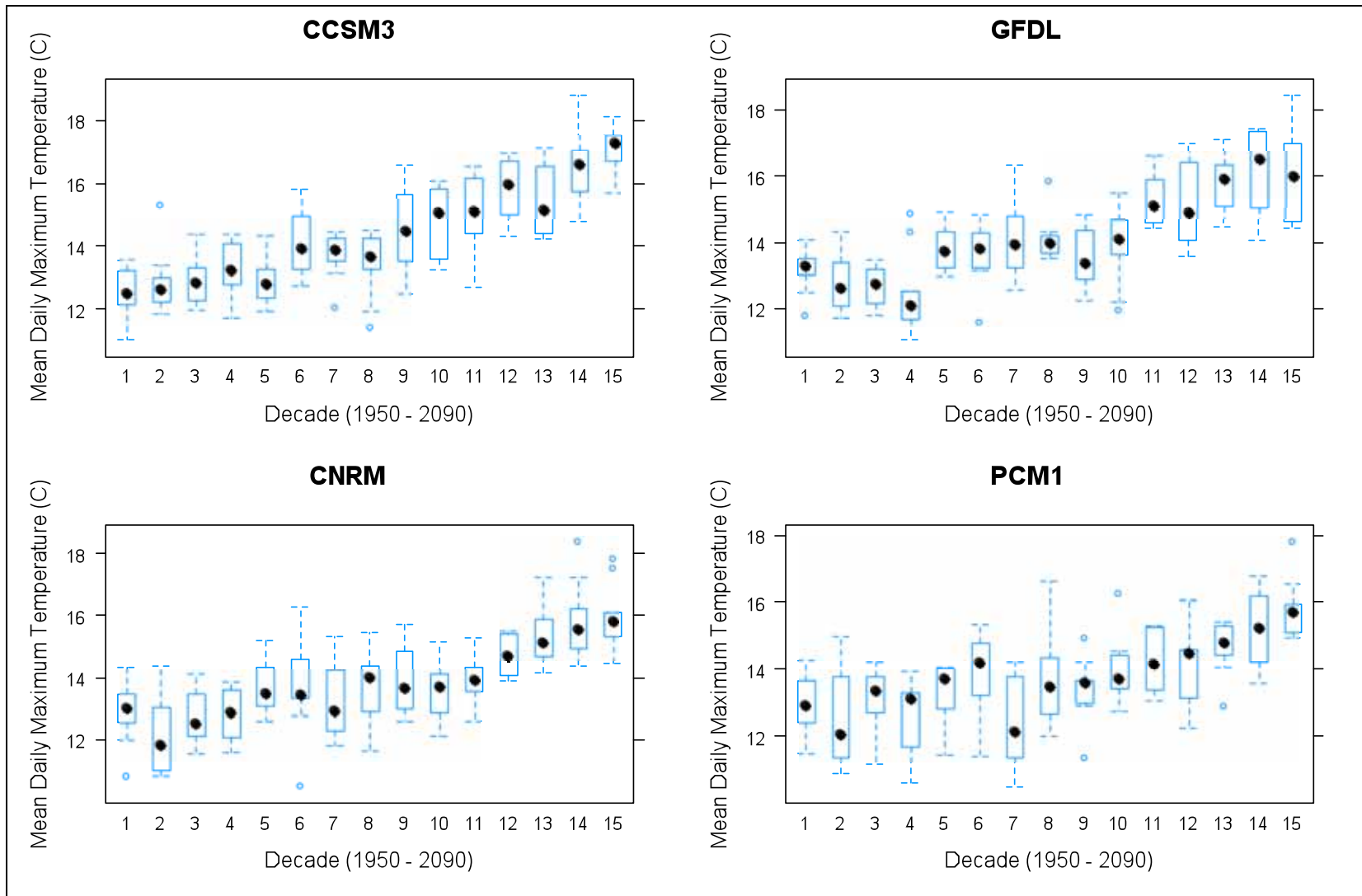
Strategies that do something effective - that don't just let nature succumb to climate change - are hard to come by.

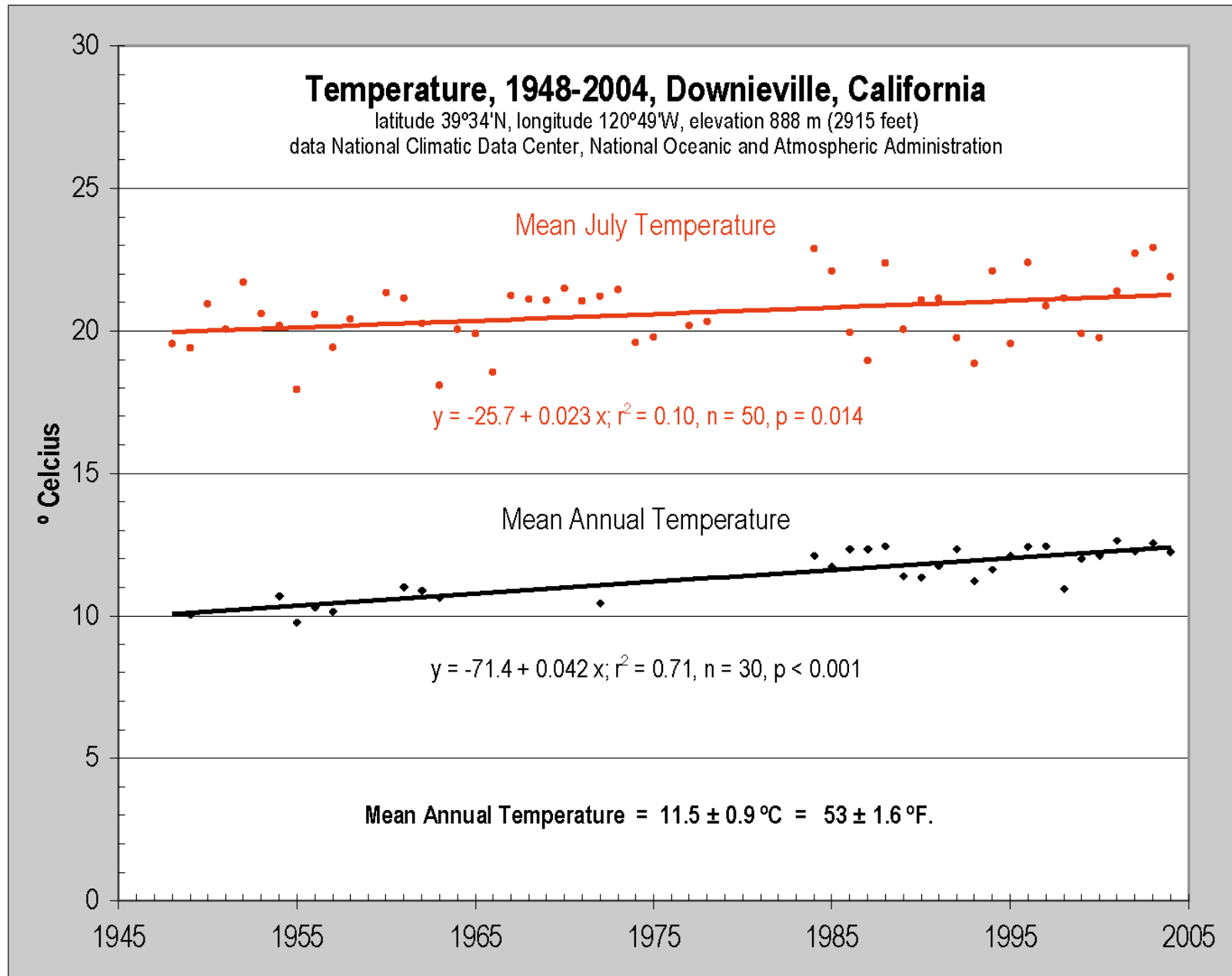
Smith and Gow 2008



Winter Mean Max Temperature

Downscaled Projections, A2, Mid-Sierra Transect





Analysis and graph from P. Gonzalez.

“one forest” approach

site specific

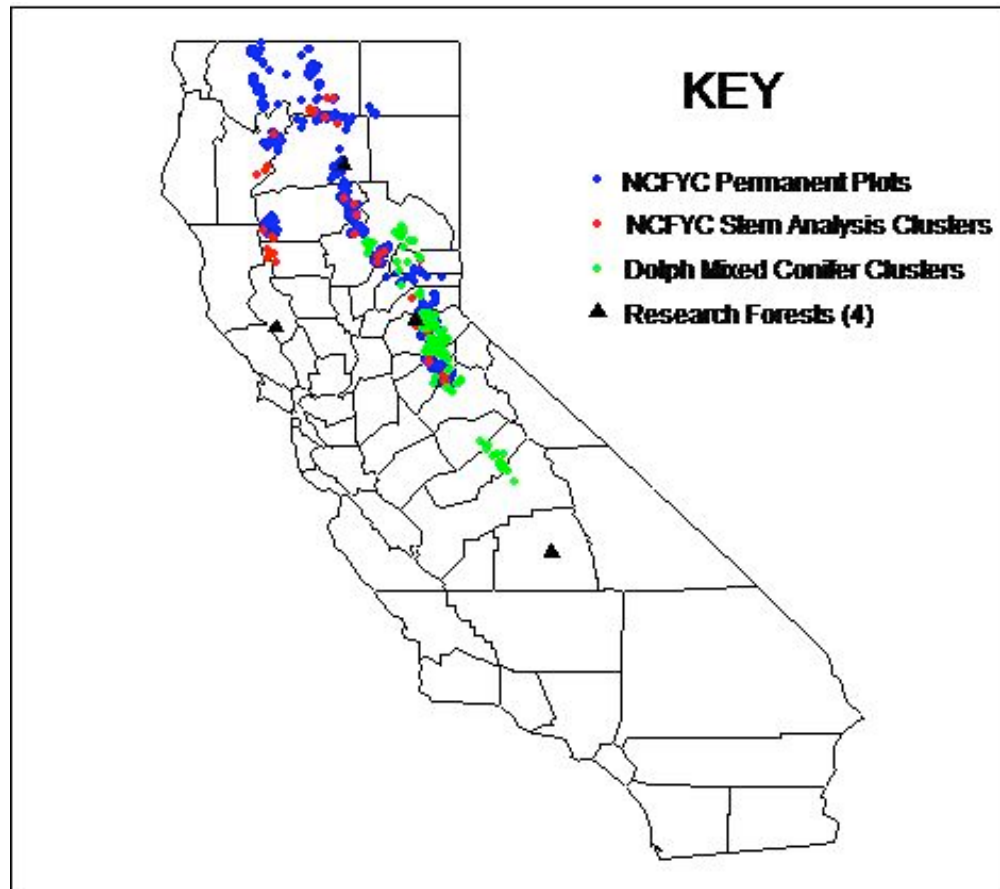
management time horizon (50 yrs)

realistic operational constraints



Forest Growth Models

- **Forest Yield Models/Empirical (Monserud 2003)**
 - CRYPTOS, CACTOS, FVS, Conifers, PPYMod, PPSIM
- **Ecological Gap Models**
- **Process/Mechanistic Models**
 - Stand-BGC (Milner et al. 2003)
 - PnET-CN (Ollinger et al. 2002).
- **Ecological Compartment Models**
 - Process model of fluxes
- **Vegetation Distribution Models**
 - MC1 (Lenihan et al. 2006), DGVMs: plant functional types
- **Hybrid Models**
 - 3-PG (Landsberg and Waring 1997), BIOMOVE (Hannah et al. 2009)



Classic approach with a twist

Climate-sensitive growth and yield model.

Specifically rebuild simulation engine of the Forest Vegetation Simulator (FVS)

Data mining (or data dredging)

Gobs of growth data

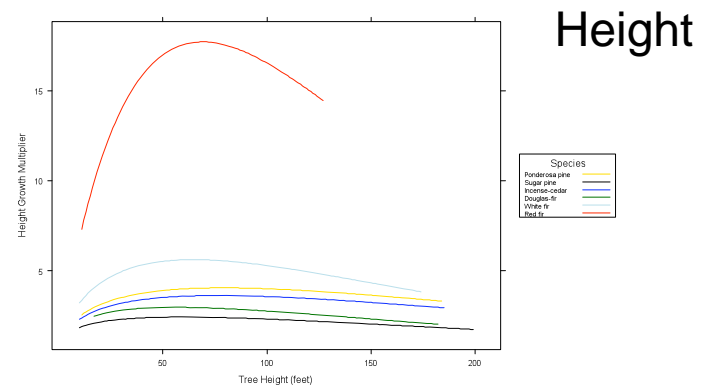
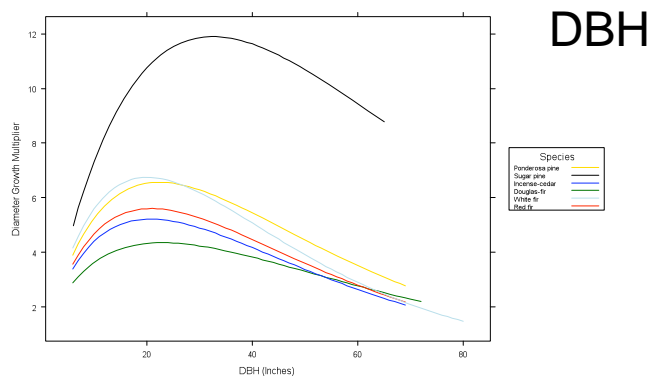
Extract past climate from PRISM

Extract soil parameters from NRCS

Data Source	Years Covered (approx.)	No. of Plots	No. of Trees	No. of Diameter Increments	No. of Diameter Remeas.	No. of Height Increments	No. of Height Remeas.
NCStem	1965-1980	105	5,465	4,639	0	2,436	0
NCPlot	1961-1998	622	31,807	3,725	39,741	2,991	44,025
DolphMC	1958-1988	397	31,807	4,436	284	1,417	150

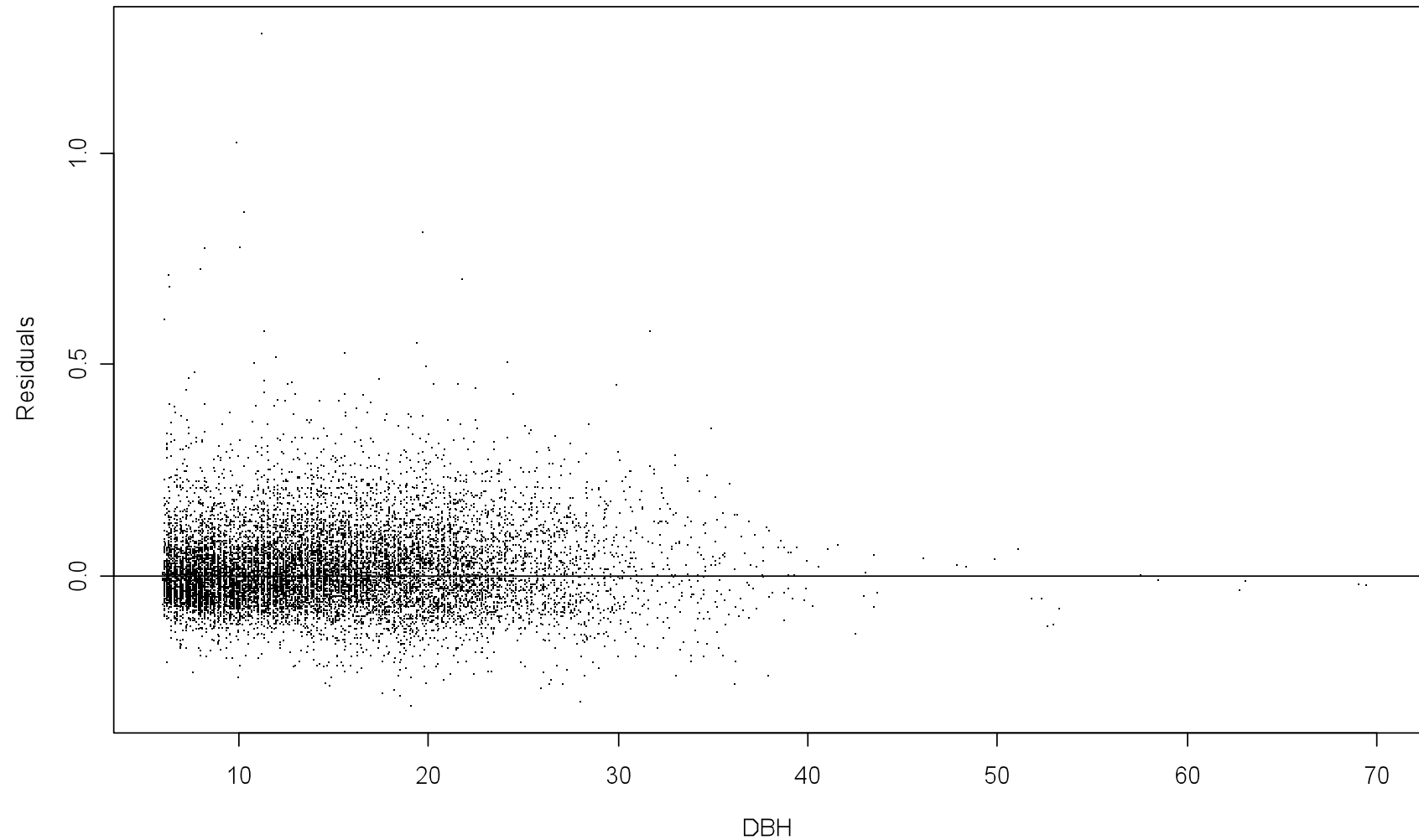
General Model Structure

$$\begin{aligned}
 E[\ln(\text{GR})] = & b_0 + b_1 \ln(\text{dbh}) + b_2 (\text{dbh}) + b_3 \text{CR} + b_4 \left(\frac{\text{PBAL}}{\ln(\text{dbh}+1)} \right) + \\
 & b_5 \text{PRECIP} + b_6 \text{TEMP} + b_7 \text{SL} + b_8 \text{SL}[\cos(\text{ASP})] + \\
 & b_9 \text{SL}[\sin(\text{ASP})] + b_{10} \text{SL}[\ln(\text{ELEV}+1)] + \\
 & b_{11} \text{SL}[\ln(\text{ELEV}+1)] \cos(\text{ASP}) + \\
 & b_{12} \text{SL}[\ln(\text{ELEV}+1)] \sin(\text{ASP}) + b_{13} \text{SL}[\text{ELEV}]^2 + \\
 & b_{14} \text{SL}[\text{ELEV}]^2 \cos(\text{ASP}) + b_{15} \text{SL}[\text{ELEV}]^2 \sin(\text{ASP}) + \\
 & b_{16} \text{ELEV} + b_{17} \text{ELEV}^2 + b_{18} \text{Albrx} + b_{19} \text{Albry} + e_{ik} + e
 \end{aligned}$$



Validation of ponderosa pine diameter growth model, WS-Clim 2.0

Residuals = Predicted growth-measured growth



Scenario:

Start with 20-yo pine plantation
Grow 20 yrs, thin to 75 ft²/ac
Grow 30 more years
50 year projection



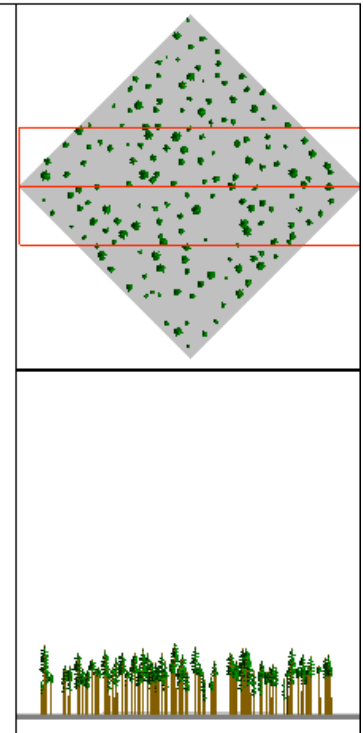
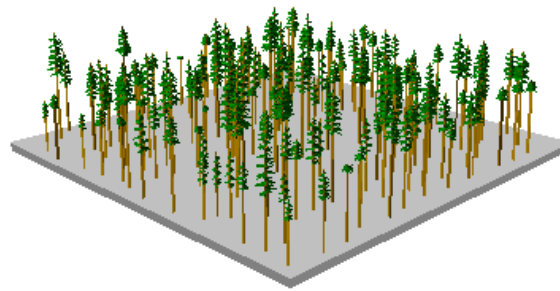
Initial conditions

Density: 295 trees/ac

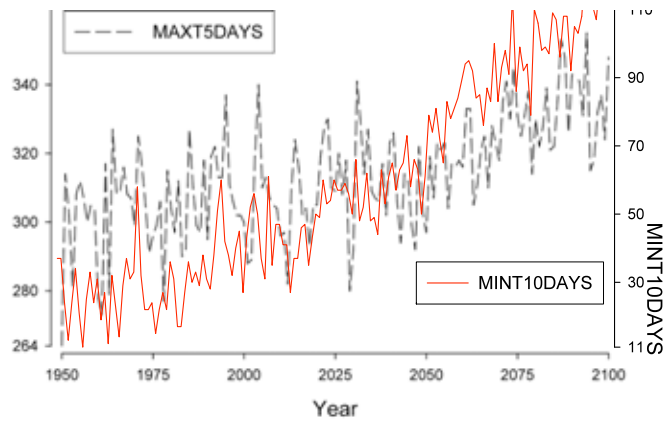
Basal area: 72 ft²/ac

Volume: 794 ft³/ac

Below average productivity

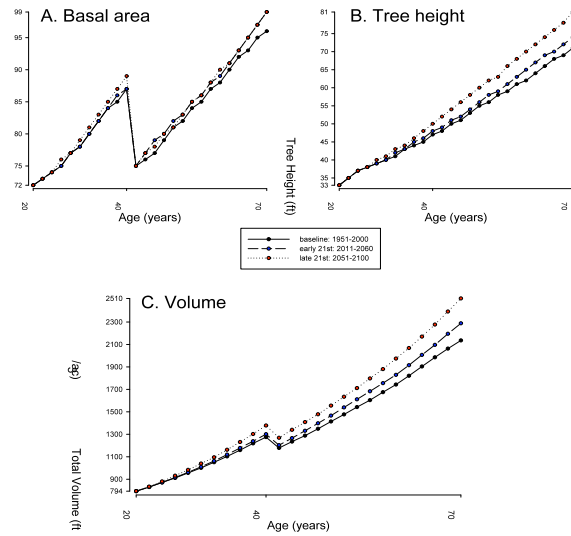


Degree-day variables captured impact of temperature on growth better than straight temperature. MINT10DAYS changed the most.



Generate relevant climate variables from downscaled GCM models (3) and emission scenarios (2) for a specific pine forest in northern California.

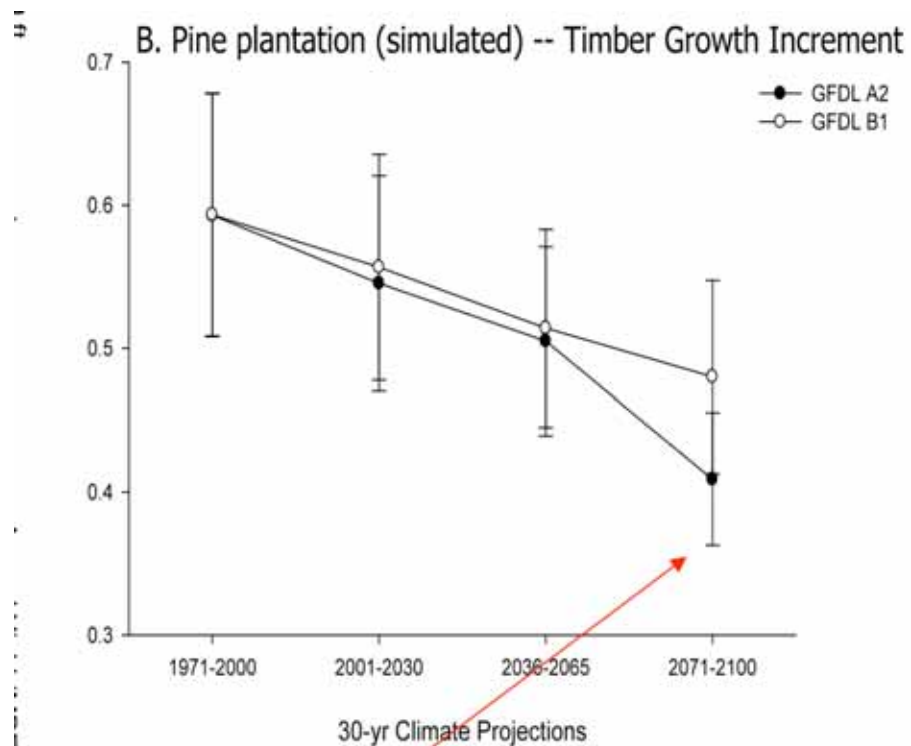
	Time Period	PREC (mm)		MAXT5DAYS (days)		MINT10DAYS (days)		TRANGE (°C)	
		A2	B1	A2	B1	A2	B1	A2	B1
GFDL CM2.1	1951-2000	372.0	372.0	310.9	310.9	30.9	30.9	15.2	15.2
		(83.0)	(83.0)	(14.1)	(14.1)	(10.8)	(10.8)	(0.6)	(0.6)
	2011-2060	347.9	388.6	323.3	322.6	52.9	47.4	15.6	15.4
		(74.8)	(88.9)	(11.9)	(12.8)	(11.9)	(11.1)	(0.7)	(0.7)
	2051-2100	344.2	369.9	336.9	327.9	78.1	57.6	16.0	15.6
		(83.9)	(84.2)	(84.2)	(12.9)	(16.1)	(11.4)	(0.6)	(0.7)
CNRM CM3	1951-2000	494.9	494.9	305.0	305.0	29.5	29.5	14.5	14.5
		(125.2)	(125.2)	(13.4)	(13.4)	(10.6)	(10.6)	(0.7)	(0.7)
	2011-2060	539.8	546.5	311.1	312.5	57.4	55.3	14.4	14.5
		(145.5)	(128.5)	(12.6)	(11.6)	(13.3)	(11.7)	(0.6)	(0.6)
	2051-2100	528.2	546.5	327.4	316.9	94.2	71.1	14.2	14.7
		(110.4)	(117.9)	(12.2)	(14.8)	(14.3)	(10.6)	(0.5)	(0.7)
NCAR PCM1	1950-1999	498.6	498.6	315.4	315.4	25.3	25.3	15.3	15.3
		(152.1)	(152.1)	(14.5)	(14.5)	(7.3)	(7.3)	(0.6)	(0.6)
	2011-2060	520.2	549.4	319.8	320.7	41.7	33.7	15.1	15.2
		(128.0)	(143.0)	(13.2)	(11.9)	(11.3)	(7.5)	(0.6)	(0.6)
	2050-2099	490.1	506.0	334.4	328.7	59.4	42.3	15.4	15.4
		(129.0)	(108.4)	(12.6)	(13.5)	(12.8)	(9.6)	(0.6)	(0.7)



emission scenario = A2
 GCM = CNRM-CM3
 Battles et al. 2009.

Sensitivity Analysis: WS-Clim 1.0

	Harvest	Final	Net	% Change
Baseline	146	2194	1546	--
PREC +10%	146	2195	1547	0.06
PREC - 7%	146	2192	1544	-0.12
MAXT5DAYS +10%	186	2340	1732	12
MAXT5DAYS +4%	166	2264	1636	5.8
MINT10DAYS +219%	155	2674	2035	31.6
MINT10DAYS +67%	149	2267	1622	4.9
TRANGE +5%	147	2226	1579	2.1
TRANGE - 2%	147	2181	1534	-0.78



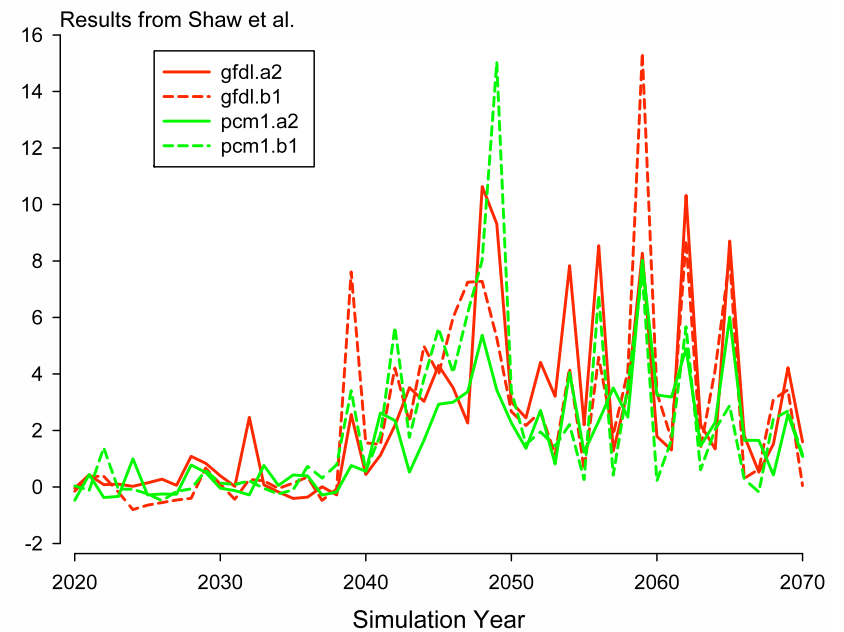
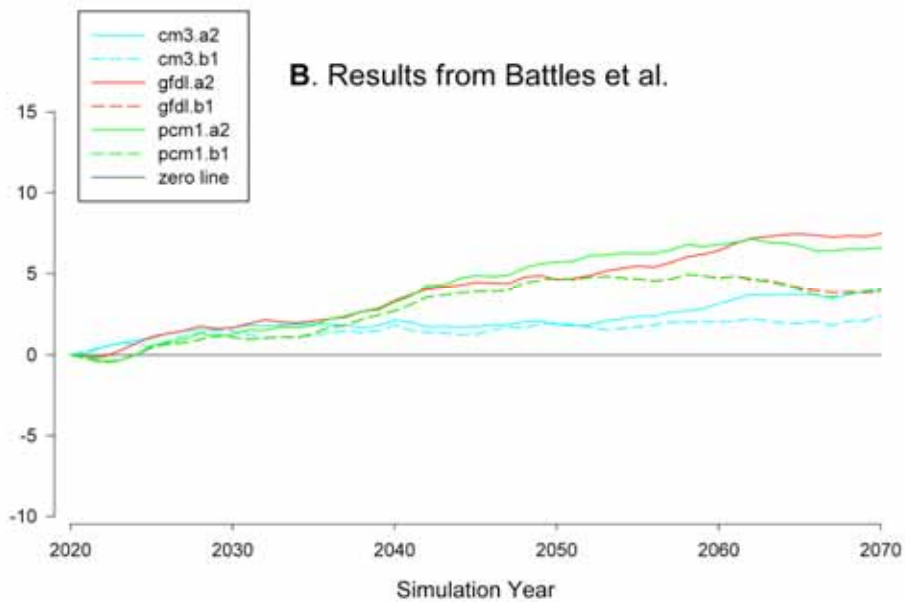
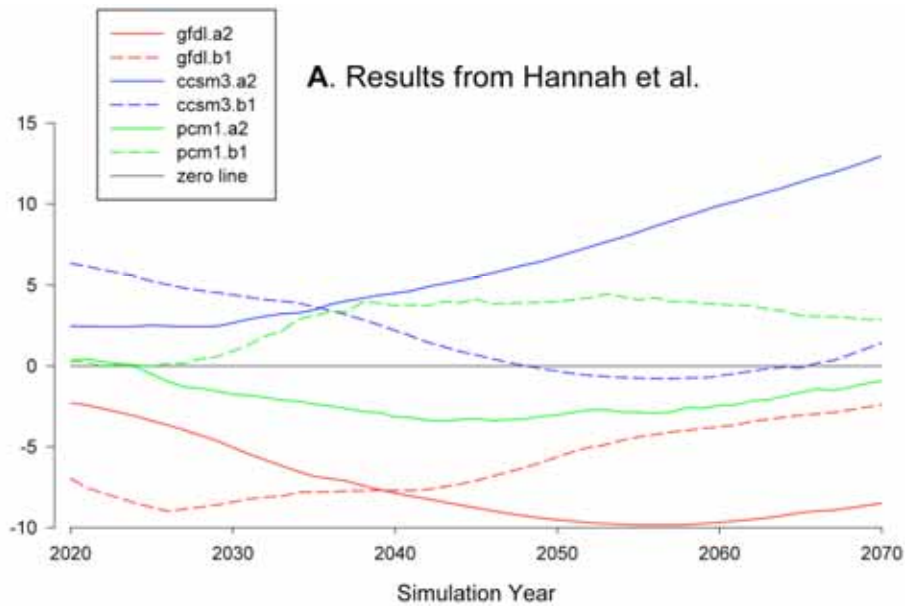
Medium-high temperature scenario
28% increase in yield by 2100

Battles et al. 2009. CEC report

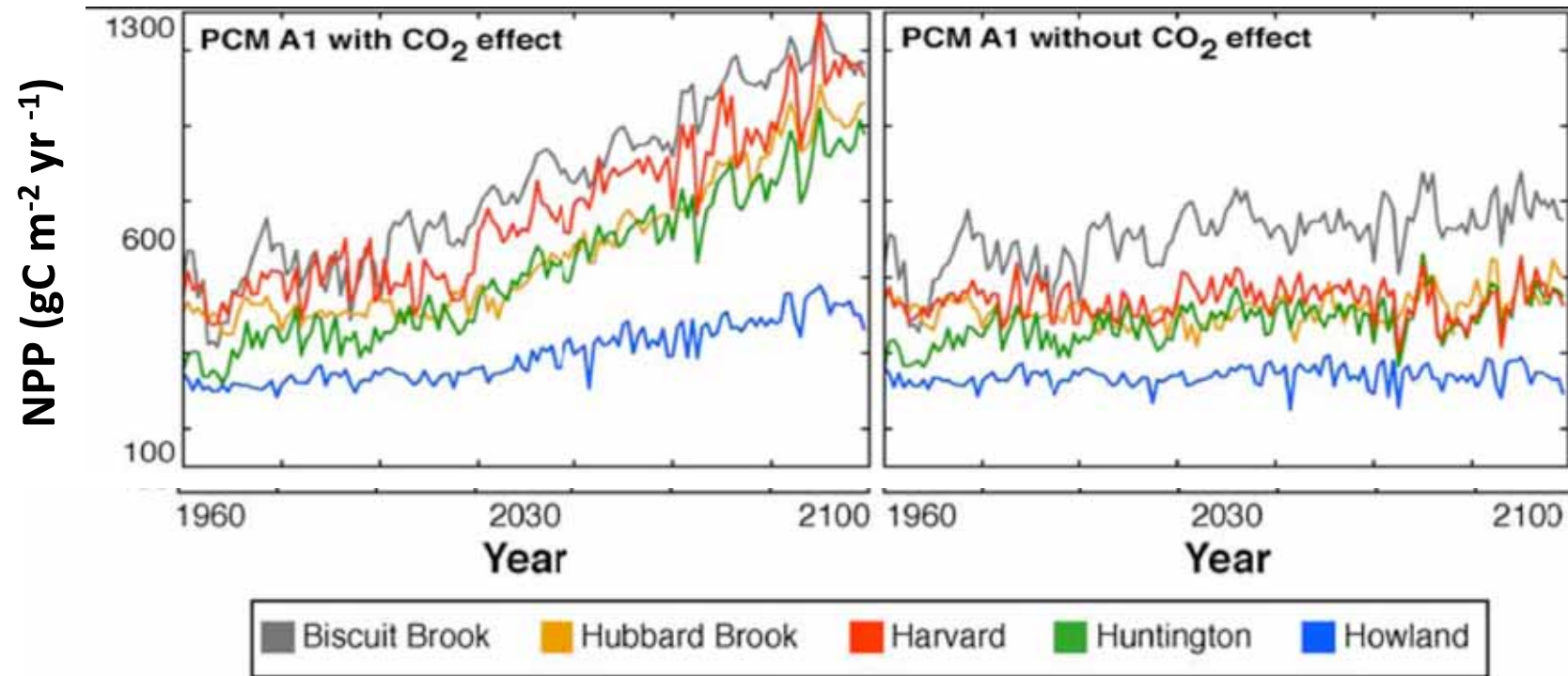
Medium-high temperature scenario
30% reduction in yield by 2100

Battles et al. 2008. Climatic Change
87:S193–S213

Need: Compare models; understand uncertainties.



Example results: PnET-CN model of forest carbon (C) with downscaled climate projections.



Ollinger et al. 2008. Mitig Adapt Strat Glob Change 13:467–485